STATE OF VERMONT
PUBLIC SERVICE BOARD

Amended Petition of Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. for amendment of their Certificate of Public Good and other approvals required under 30 V.S.A. § 231(a) for authority to continue after March 21, 2012, operation of the Vermont Yankee Nuclear Power Station, including the storage of spent nuclear fuel	)))))))	Docket No. 7862

DIRECT TESTIMONY OF MARCIA GREENBLATT
ON BEHALF OF THE
VERMONT DEPARTMENT OF PUBLIC SERVICE

October 22, 2012

Summary: Dr. Greenblatt's testimony presents the results of an evaluation of thermal discharge associated with the Vermont Yankee Nuclear Power Station (the "VY Station"). This evaluation identifies potential concerns with the applicability and the protectiveness of the thermal discharge limits currently regulating the VY Station. Dr. Greenblatt concludes that the existing analyses performed to support the existing thermal limits do not include the full extent of the thermal discharge footprint, and may not capture conditions that may adversely impact the biological community.

Dr. Greenblatt sponsors the following exhibits:

Exhibit PSD-MG-01	Curriculum Vitae
Exhibit PSD-MG-02	HydroAnalysis, Inc., Review of Vermont Yankee Thermal Discharge Permit Requirements and Analysis of Connecticut River Water Temperature and Flow (August 17, 2012)
Exhibit PSD-MG-03	Letter from Kenneth Sprankle, U.S. Fish and Wildlife Service, to Deborah Markowitz, Vermont Agency of Natural Resources (March 16, 2012)
Exhibit PSD-MG-04	HydroAnalysis, Inc., Review of Vermont Yankee Thermal Discharge Modeling (February 6, 2012)

Q1. Please state your name, business address, and occupation.

A1. Marcia Greenblatt, 74 Bedford St., Lexington MA. I am a Senior Managing Hydrologist at Integral Consulting, Inc. My complete CV is attached as Exhibit PSD-MG-01.

Q2. Please state your educational and professional background.

A2. I have a B.S. in Forestry from University of Massachusetts, Amherst and a M.S. and Ph.D. in Water Resources Engineering from University of California, Berkeley. I am a licensed professional engineer in the Commonwealth of Massachusetts. I have worked as an environmental consultant for 15 years.

Q3. Have you previously testified before the Vermont Board of Public Service?

A3. No.

Q4. Please summarize your background and experience.

A4. I am a water resources engineer specializing in hydrodynamic, water quality, and sediment investigations, including development and application of numerical models, and data analysis and presentation. I have designed and performed several modeling studies, applying both simple and complex numerical models to predict hydrodynamic flows; sediment erosion, transport, and deposition; and water quality. I have performed numerous modeling studies for mixing zone evaluations to support National Pollutant Discharge Elimination System permit renewals as well as operational evaluations, with several of these studies focused on thermal discharges. My projects have included data

needs assessments, field program design, evaluation and integration of existing data, numerical model application, and agency negotiation.

Q5. What is the purpose of your testimony?

A5. The purpose of my testimony is to discuss thermal discharges from the Vermont Yankee Nuclear Power Station (the "VY Station") into the Connecticut River.

Q6. Please describe how and where water is discharged from the VY Station to the Connecticut River.

A6. The VY Station is a boiling water nuclear reactor with a rated core thermal power level of 1,912 megawatts (MW), providing a gross electrical output of 620 MW. The remainder of the energy, 1,292 MW, is removed as heat by a circulating water system as it passes by a condenser and discharges either as heated water from an outfall to the Connecticut River or as steam via mechanical draft cooling towers to the atmosphere. The VY Station is located on the west shore of Vernon Pool, which is an impoundment on the Connecticut River created by the Vernon Dam that extends approximately 25 miles above the location of the VY Station's outfall and 0.5 miles below the VY Station's outfall. Vernon Dam is approximately 0.5 miles downstream of the VY Station's outfall. At Vernon Dam, there is a fish ladder intended to allow upstream fish passage, and a fish bypass, louvers, and fish pipe intended to allow downstream fish passage.

Q7. Are thermal discharges subject to regulation?

A7. Yes. Heat is a pollutant. Therefore, discharges of heat (or thermal discharges) into the Connecticut River are subject to the Clean Water Act and may require a permit under the National Pollutant Discharge Elimination System ("NPDES").

Q8. Does the VY Station have a NPDES permit?

A8. Yes. It was issued by the Vermont Agency of Natural Resources ("ANR") on March 30, 2006.

Q9. What does that NPDES permit require regarding thermal discharges?

A9. The thermal limits specified in the NPDES permit, issued March 30, 2006, are as follows:

(1) During the period October 15 through May 15:

- The temperature at a monitoring station approximately 1.2 miles downstream from the VY Station discharge (Monitoring Station 3) shall not exceed 65ºF;
- The "rate of change of temperature" at Monitoring Station 3 shall not exceed 5 ºF per hour. The rate of change of temperature is defined in the NPDES permit as the difference between the consecutive hourly average temperatures.
- The "increase in temperature above ambient" at Monitoring Station 3 shall not exceed 13.4ºF. The increase in temperature above ambient is defined in the NPDES permit as the "plant induced temperature increase as shown by [E]quation 1.1."

(2) During the period May 16 through October 14, the permitted calculated increased temperature above the ambient water temperature at Monitoring Station 3 depends

on the time of year and the temperature measured at a monitoring station approximately 3.8 miles upstream from the VY Station (Monitoring Station 7), as follows:

Monitoring Station 7 Temperature	Permitted Increase in Temperature above Ambient Water Temperature at Monitoring Station 3	
	May 16 – June 15	June 16 – October 14
$>78^0$F	2^0F	2^0F
$>63^0$F, $\leq 78^0$F	2^0F	3^0F
$>59^0$F, $\leq 63^0$F	3^0F	4^0F
$\geq 55^0$F, $\leq 59^0$F	4^0F	5^0F
$<55^0$F	5^0F	5^0F

(3) The hourly average water temperature at Monitoring Station 3 from June 16 through October 14 shall not exceed 85ºF.

Q10. In your discussion of the VY Station NPDES permit limitations above, you refer to an "Equation 1.1" as determining the permitted amount of increase in water temperature above ambient. What is Equation 1.1?

A10. Equation 1.1 is used to calculate the "plant induced temperature increase" (ΔTr), or the theoretical amount by which the VY Station increases the temperature (in degrees

Fahrenheit) of the Connecticut River at Monitoring Station 3. The equation is as follows:

$$\Delta Tr = H/ (\rho Cp Qr)$$

where H is the heat rejection rate to the river (in megawatts), ρ is the density of water, Cp is the specific heat of water, and Qr is the river flow rate (in cubic feet per second).

Q11. What is "heat rejection"?

A11. The VY Station uses water to cool the plant condensers. The heat added to the cooling water is then either dissipated to the atmosphere as steam through cooling towers or discharged (as heated water) to the Connecticut River. This process of giving off heat is termed heat rejection. The heat rejection to the Connecticut River through thermal discharges and to the atmosphere through cooling towers at the VY Station depends on the patterns of cooling tower operation. Equation 1.1 includes the input of the VY Station heat rejection to the river only.

Q12. How is heat rejection rate determined?

A12. According to annual reports submitted by VY under its NPDES permit, input into Equation 1.1 comes from "the plant environmental thermal sensor network."

Q13. Does the operator of the VY Station—Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. (collectively "Entergy")—share the data from its environmental thermal sensor network?

A13. I am not aware of any presentation of these data.

Q14. Without the data from the VY Station's environmental thermal sensor network, is it possible to determine what the heat rejection rate is from the VY Station?

A14. No.

Q15. How is river flow rate determined?

A15. River flow rate is computed using observations of the "stage" (or water level height) of the river obtained by Entergy from sensors installed at the Vernon Dam. Entergy uses "rating curves" to convert the stage to the flow rate (which is reported in cubic feet per second, or "cfs") based on previous measurements. For flow rates greater than 32,000 cfs, Entergy obtains river flow data from TransCanada, which operates a hydropower facility in connection with Vernon Dam.

Q16. What is the "specific heat" of water?

A16. Specific heat is the amount of heat per unit mass needed to raise the temperature of water by a given amount.

Q17. Are there limitations to the applicability of this Equation 1.1?

A17. Yes. Equation 1.1 may not be applicable for all flow and discharge conditions. A 1978 submission to ANR by the VY Station's prior owners demonstrated the validity of Equation 1.1 only under two conditions: (1) "[d]uring periods of high and gradually

varying river flows, and while heat is discharged from Vermont Yankee at a constant rate" and (2) during daily minimum discharge flows. There was no demonstration that Equation 1.1 is valid under other conditions.

Another limitation of Equation 1.1 is that, according to a 2004 submission by Entergy to ANR in support of an amendment to the VY Station's NPDES permit, Equation 1.1 predicts the contribution of the thermal discharge to temperature rise at Monitoring Station 3 assuming that the thermal discharge is completely mixed with the river at this location.

Q18. Can one necessarily assume that thermal discharge is completely mixed with the river at Monitoring Station 3?

A18. No. I have reviewed a report submitted to ANR by HydroAnalysis, Inc. ("HydroAnalysis") in August 2012, attached as Exhibit PSD-MG-02. That report concludes that Connecticut River flows at Vernon Dam are "highly dynamic, often increasing and decreasing by large amounts (e.g., through a range of 2,000 to 8,000 cfs) once or twice each day." HydroAnalysis suggests this dynamic flow condition could result in incomplete mixing of the thermal discharge with the ambient waters, and that as a result the computation performed under Equation 1.1 may result in inaccurate estimates of temperature rise due to the thermal discharge because it assumes that thermal discharge is completely mixed with the ambient waters. While the water at Monitoring Station 3 may be fully mixed throughout the water column (i.e., from the water surface to the bottom of the river), the water discharged from Vernon Dam may not be fully mixed

if water temperatures are vertically stratified in Vernon Pool (i.e., they vary from the water surface to the bottom). Temperature data collected by Entergy in 2002 and presented to ANR in Entergy's 2004 submission show variations between the water surface and the bottom of the water column of up to 3.6°F (ASA (2004) Figures 3-4 to 3-12). The data further show that, over the 10-day period for which data are presented, there is an observed break down and reestablishment of the thermal stratification in the water column, which, like the HydroAnalysis report, further indicates dynamic flow and mixing conditions in the Connecticut River.

Q19. Are there implications if Equation 1.1 does not accurately predict the increase in temperature of the Connecticut River due to thermal discharges from the VY Station?

A19. Yes. The actual contribution of the thermal discharges from the VY Station may be greater than the values calculated by Equation 1.1. The NPDES permit was developed based on an evaluation of the aquatic ecosystem (including fish and macroinvertebrates) in the Connecticut River and how tolerant that ecosystem is to heat. The thermal limits in the NPDES permit were set to be protective of that ecosystem. If actual conditions differ from calculated conditions, there may be a thermal impact on the aquatic ecosystem that is not addressed by the NPDES permit and was not fully considered in Entergy's submissions to ANR concerning the thermal impacts of the VY Station.

Q20. Have you reviewed any documents that suggest that the actual plant-induced temperature rise of the river differs from temperature rise calculated by Equation 1.1?

A20. Yes. According to HydroAnalysis, actual measured temperature differences between Monitoring Station 3 and Monitoring Station 7 "were typically more than 2°F higher than the permitted rise" and "exceeded 7°F when the permitted temperature rise was 3°F." The calculated temperature rise in Equation 1.1 (ΔTr) accounts only for the heat contribution from the VY Station, and the existing data and analyses do not allow for confirmation that the VY Station's contribution is accurately predicted by Equation 1.1 under all flow and discharge conditions.

Q21. Does Equation 1.1 account for sources of temperature rise other than thermal discharge from the VY Station?

A21. No. As mentioned above, Equation 1.1 is subject to several limitations and predicts only the temperature rise from the thermal discharge.

Q22. Could there be other sources of heat between Monitoring Station 7 and Monitoring Station 3?

A22. Yes. As the water is pooled behind Vernon Dam and exposed to sunlight ("insolation"), its temperature could rise.

Q23. Is there any way to account for the impact of insolation?

A23. Yes. Temperature rise due to insolation could be evaluated based on data collected across Vernon Pool when the VY Station is not operating. In a March 16, 2012 letter (attached as Exhibit PSD-MG-03), the U.S. Fish and Wildlife Service ("USFWS") presented time-

series temperature data collected 2.2 miles upstream of the VY Station and in "tailwater" just downstream of the Vernon Dam. The USFWS data showed that during a period of plant outage (late April to May 25, 2010), water temperatures at the upstream and downstream locations were the same, suggesting that insolation was not heating water during this period as water passed through the Vernon Pool. In contrast, the USFWS data showed that water temperatures were generally higher after passing through the Vernon Dam and the VY Station while the VY Station was in operation. Although I have not reviewed a formal report of these data, a graphical review of these data during this time period suggests they behave reasonably and as expected. That is, the data vary diurnally by generally less than 2°F, typical of water temperatures, and the two temperature measurements vary in a similar pattern.

Entergy also reported that collected water temperature data during a 2001 plant outage. However, I have not seen sufficient data to evaluate the difference in river water temperature upstream and downstream of the VY Station during that outage.

The relative contributions of insolation and the VY Station's thermal discharges to the temperature of the Connecticut River also could be evaluated with a numerical model. Entergy has developed a detailed, three-dimensional, time-varying numerical model of the Vernon Pool. The modeling study was performed in 2004 to simulate the impacts of a requested increase in the thermal limits permitted under the NPDES permit. The objective of the modeling study was to "determine what effects, if any, the increased VY thermal discharge would have on the thermal structure of the River." The model was

applied to simulate conditions during the summer period (May 16 through October 14) and during the period of fishway operation at the Vernon Dam.

The model could be applied to predict temperatures in Vernon Pool under summertime conditions with and without the VY Station's thermal discharge. A comparison of these model scenarios would allow for an assessment of the contribution of the VY Station's discharge to the heating of the waters within Vernon Pool. The model could be applied over a range of conditions and could be applied to develop time-varying estimates to better understand the potential impact of varying flow and discharge conditions on thermal heating and thermal mixing. The model, if applied appropriately, could provide a tool to verify or identify any inaccuracies of Equation 1.1 under a range of conditions. Given Entergy's assertion that a predictive model has been developed that provides a good representation of hydrodynamic and thermal conditions, this model could be applied to evaluate the relative contributions of insolation and the thermal discharge to the temperature of the Connecticut River.

Q24. Did Entergy's model show compliance with the NPDES permit?

A24. No. The model did not extend to Monitoring Station 3, the NPDES permit compliance point. To be able to directly compare the model results to the predicted plant induced temperature using Equation 1.1 of the NPDES permit, the model domain would need to be extended at least 0.5 miles downstream of the Vernon Dam to include this location. Although I understand that Entergy is working to develop a thermal model that will include downstream data, I am not aware that any such model has been made available by

Entergy as of the date of this testimony. A robust model would also need to be applied to the range of observed conditions, including the rapidly varying conditions that occur in the river.

Q25. Did Entergy's 2004 model contain time-varying scenarios?

A25. No. When Entergy performed the modeling study in 2004, it did not include any time-varying scenarios. That application of the model does not allow validation of Equation 1.1, which is applied under all conditions but known to have limitations during time-varying conditions.

Q26. Does application of the model without time-varying scenarios create any concerns?

A26. Yes. Entergy developed and calibrated the model to provide predictions for time-varying conditions (e.g., hourly river flows or hour discharge and resulting hourly water temperature predictions). However, when the model was applied to predict water temperatures with the requested additional heated discharge, the model was applied to constant, "steady-state" conditions (i.e., constant river flow that does not vary over time), and model predictions were presented as a single set of values (i.e., steady predicted temperatures in Vernon Pool that do not vary over time). Given variations in air temperature and solar radiation that occur throughout each day, and observed variations in flow, which are not captured by the model as it was applied, it is possible that there are varying conditions that present an adverse impact to the biological community (for example, rapidly changing temporal water temperatures) that are not captured in the

modeling study. The application of the model with time-varying scenarios would have provided a more detailed characterization of the nature and extent of the thermal discharge footprint, allowing for more meaningful evaluation of potential impact on fisheries as well as long-term predictions that may have identified and characterized conditions not captured with the steady-state model application.

A February 2012 report by HydroAnalysis, attached as Exhibit PSD-MG-04, noted the following further concerns with the application of the model:

(1) The model evaluates the potential impact of the additional temperature load, which "is seemingly based on the presumption that the previous 316 demonstrations had adequately characterized the thermal conditions in the Connecticut River." In other words, the model did not evaluate the impact of the requested increase in thermal limits in combination with prior permitted increases, but rather the impact only of the requested increase itself. Such an evaluation would ignore the cumulative impact of the thermal discharges (as well as other stressors on the aquatic life in the river).

(2) The model does not include the full extent of the river potentially subject to thermal impacts. "Previous 316 demonstrations (1978 and 1990) the thermal plume was measured and/or predicted to extend at least to the Holyoke Dam, 55 miles downstream [from the VY Station]. This downstream area was not included in the model evaluation." As discussed above, Entergy's 2004 model did not even extend to Monitoring Station 3,

the NPDES permit compliance point approximately 1.2 miles downstream from the VY Station discharge.

Based on the above concerns, HydroAnalysis concluded that the model "was insufficient to support fisheries studies submitted as part of the 2004 demonstration report." More specifically, HydroAnalysis concluded that Entergy's study "failed to consider the entire reach of the river affected by the thermal discharge, the synergistic effects of the Vernon Dam operations, and the appropriate worst-case conditions. As a result there is insufficient information for the fisheries analyses to determine if the river can support a balanced indigenous fish population." The existing analyses performed to support the existing thermal limits do not include the full extent of the thermal discharge footprint and may not capture conditions that may adversely impact the biological community.

Q27. Is there information to support HydroAnalysis' conclusion that the plume extends downstream?

A27. Yes. Previous studies have indicated that the thermal discharge footprint may extend downstream up to at least 50 miles below the VY Station's discharge. A 1978 submission by Entergy's predecessor owners of the VY Station presented results of a study where water discharged from the VY Station was tagged with dye and monitored as it traveled downstream to a monitoring point approximately 40 miles downstream of the Vernon Dam. At that monitoring point, approximately 40% of the heat added to the river at the VY Station was shown to remain in the river during some flow conditions. In addition,

modeling results reported in a 1990 submission by Entergy's predecessors showed that heated water from the VY Station could have increased the temperature of the river at Holyoke Dam—approximately 58 miles downstream of the VY Station—by up to 1.5°F.

In addition, the August 2012 report by HydroAnalysis evaluated temperature data collected by USFWS at 11 locations in the Connecticut River. According to the March 16, 2012 letter from USFWS to ANR, the temperature data collected by USFWS showed that temperatures measured downstream were consistently the same temperature as observed at Monitoring Station 3, "indicating that the temperature rise added to the Connecticut River near Vernon Dam is retained for a distance of at least 22.5 miles downstream during this (2010) time period. This is likely due to several factors, including the Vermont Yankee thermal discharge, the Vernon Dam impoundment, and meteorological conditions."

Q28. Are there implications of not evaluating potential thermal impacts downstream?

A28. Yes. The thermal limits are set in the permit to be protective of aquatic ecosystems. In Entergy's 2004 submission to ANR, in which it sought to increase the allowed thermal limits of discharge from the VY Station, thermal impacts downstream of the Vernon Dam were not evaluated. Without this evaluation, it cannot be determined if the increased limits in the existing permit are protective of the communities downstream.

Q29. Does the evidence that you have reviewed lead you to conclude that thermal discharges from the VY Station are not adversely affecting the aquatic ecosystem?

A29. No. Elevated temperatures at both Monitoring Station 3 and in the fish ladder at the Vernon Dam may be a concern for the aquatic community. In its March 16, 2012 letter, USFWS expressed concern that observed temperatures in the fish ladder at the Vernon Dam and conditions in the immediate vicinity of the thermal discharge may not be protective of the aquatic ecosystem. For example, while USFWS has established that the downstream passage window for juvenile Atlantic salmon (or "smolts") begins on April 1, the VY Station is permitted to discharge at its most liberal annual thermal limits until May 16, which is 1.5 months after the smolt downstream passage window begins. This is inconsistent with fishway operating requirements imposed on other plant operators on the Connecticut River. A 2011 study cited by USFWS indicated that only 0.3% of the shad that swam upstream through a fish passage structure at the downstream Turners Falls Dam subsequently passed the Vernon Dam by the VY Station. USFWS concluded that there may be multiple factors contributing to thermal stressors and ecosystem response in the Connecticut River that may not be well understood. If recent studies (which may not have been available during earlier evaluations) indicate a potential for thermal impacts from ongoing conditions, these studies should be considered in the reevaluation of the allowable thermal discharge from the VY Station.

Q30. Does the evidence that you have reviewed lead you to conclude that continued operation of the VY Station by Entergy will not have an undue adverse effect on water purity and the natural environment, as described in 30 V.S.A. 248(b)(5)?

A30. No. There is substantial uncertainty surrounding the impacts of thermal discharge from the VY Station. My evaluation identifies concerns with the applicability and the protectiveness of the thermal discharge limits currently regulating the VY Station.

Q31. Does this complete your testimony?

A31. Yes, at this time.